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SOME CONDITIONS INFLUENCING THE YIELD OF HOPS.

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SOME CONDITIONS INFLUENCING THE YIELD OF HOPS.[a]

INTRODUCTION.

In certain of the hop-growing sections of the United States the opinion is frequently expressed that there has been a progressive decline in the annual average yield per acre extending over a term of years. In other sections growers believe that the yields are at least as great now as they have ever been. Some support for each view is found in Table I, adapted from Bulletin No. 50 of the Bureau of Statistics, U. S. Department of Agriculture.

TABLE I.—*Average yield of hops, by States, for the census years 1880, 1890, and 1900.*

State.	Average yield per acre.		
	1880.	1890.	1900.
	Pounds.	*Pounds.*	*Pounds.*
California	1,291	1,648	1,469
New York	554	547	630
Oregon	804	1,155	951
Washington	1,317	1,626	1,287

[a] This paper clearly illustrates the importance of applying exact methods in studying the factors influencing crop yields. The facts here set forth were obtained from a study of the yield of hops, and they offer suggestions of great practical importance to every hop grower. It is desirable to emphasize the point that the most profitable methods of culture and handling can not be accurately determined by general observation alone, since many details will be overlooked which, apparently trifling in themselves, become of great importance when taken in the aggregate. For example, the direct loss due to the lack of a stand alone may not be appreciated until a survey is made and the percentage ratio determined.

The practical points presented in this publication were developed in connection with an extended investigation of American hop growing and handling which is being carried on by Dr. W. W. Stockberger, Pharmacognosist, assisted by Mr. James Thompson, expert, under the general direction of Dr. R. H. True, Physiologist in Charge of Drug-Plant Investigations, and it seems desirable to make these results immediately available in the form of a circular.—G. H. POWELL, *Acting Chief of Bureau.*

The figures given in this table were taken at ten-year intervals, and in the absence of those for the intervening years they are of little value in determining either an increase or a decrease in the average annual yield. Assuming, however, that the apparent diminution of yield for the State of California as indicated by the table was real, a thorough study of an individual acre in the central part of the State was begun in 1909 for the purpose of determining some of the factors which might be responsible for diminished production.

The results of this study clearly indicate that closer attention to certain cultural details should result in a substantial increase in yield.

THE METHODS EMPLOYED IN THE INVESTIGATION.

The acre selected for study represented, as far as inspection alone could determine, the average of conditions existing in several contiguous fields of hops aggregating about 600 acres. The soil, a rich sandy loam, had been under hops continuously for the last ten years. The rows were 7 feet apart, running from east to west, and the hills were approximately 6½ feet apart in the rows. The hops were trained on strings about 18 feet long, depending from the wires of the usual type of high-wire trellis.[a]

When the crop was ready for harvesting, a plat was made of the entire acre and a definite number assigned to every hill. The hops were then picked from each hill separately, weighed, and the weight recorded opposite the number assigned to that respective hill. The number of vines to the hill, the occurrence of male, dwarf, "bastard," nonproductive, and missing hills, and the general characteristics of the product of each hill were also recorded.

EFFECT OF IMPERFECT STAND ON YIELD OF HOPS.

When the observations were tabulated it became evident that the yield had been heavily reduced through the occurrence of a large number of nonproductive and missing hills, as will be seen from the following:

Hills producing hops	853
Hills having vines with no hops	42
Missing hills	56
Hills with dwarfed vines	1
Hills having "bastard" vines	5
Hills having only male vines	10
Total	967

Deducting the number of male hills, the presence of which is held to be necessary for the proper development of the crop, there should have been on this acre 957 productive hills, as against 853 hills

[a] See Farmers' Bulletin 304, p. 14.

actually bearing hops. This gives an absolute reduction of 104 hills, or 10.8 per cent. Had the entire number of hills been in bearing the yield would have been 12.1 per cent greater than that actually obtained.

The distribution of the hills having vines with no hops and of the missing hills is shown on the accompanying diagram (fig. 1). The

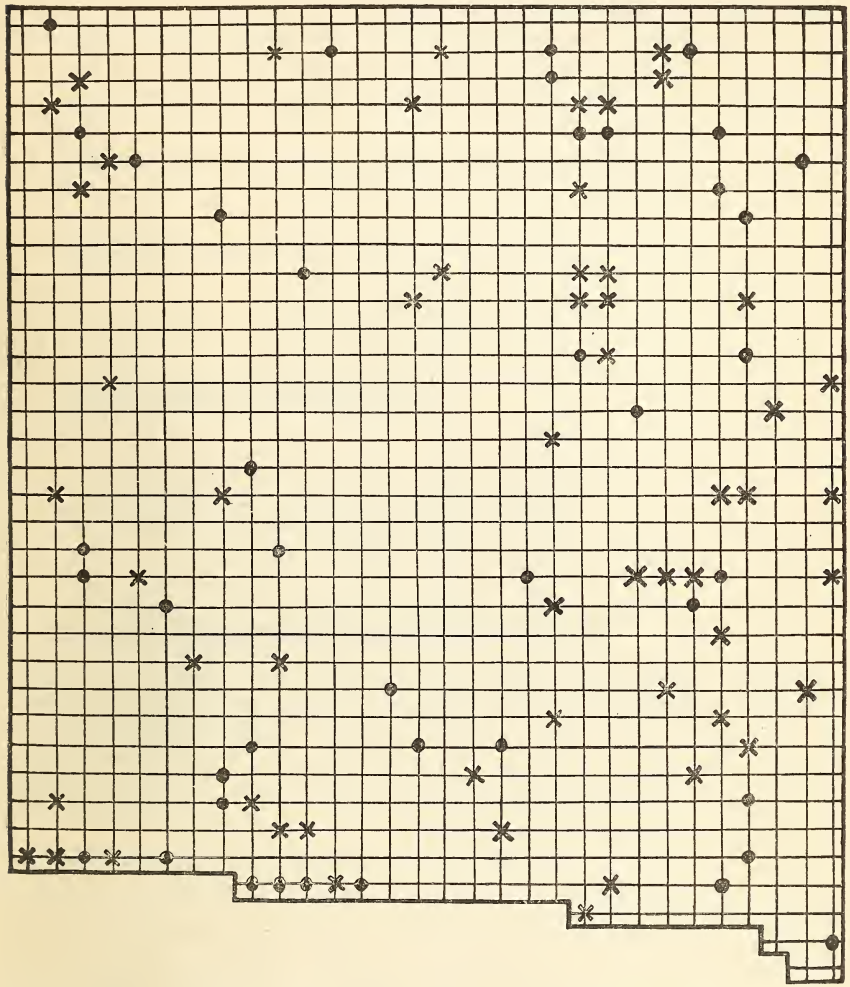

FIG. 1.—Diagram showing the distribution of nonproductive and missing hills of hops on the experimental acre in California. ● = Vines bearing no hops; × = missing hills.

dots indicate the hills having vines bearing no hops, and the crosses the missing hills. This distribution appears to be entirely one of chance and not due to variation in the soil, imperfections in the drainage, or other purely local factors.

VARIATION IN THE YIELD FROM INDIVIDUAL HILLS.

A wide variation was observed in the yield from individual hills. This ranged from a few ounces in some cases to as much as 18 pounds in others. In making the records the weight of green hops was taken to the nearest half pound, and the results have been put in tabular form, appearing in Table II. In the columns marked "Yield" the weight of green hops is given to the nearest half pound, and in the other two columns is given the number of hills, each of which gave the yield opposite these numbers in the adjacent column to the left.

TABLE II.—*Number of hills giving various yields of hops on the experimental acre in California.*

Yield.	Hills.	Yield.	Hills.
Pounds.	*Number.*	*Pounds.*	*Number.*
0.5	18	9.5	24
1.0	50	10.0	31
1.5	34	10.5	16
2.0	39	11.0	24
2.5	33	11.5	10
3.0	32	12.0	20
3.5	43	12.5	5
4.0	41	13.0	7
4.5	35	13.5	6
5.0	60	14.0	11
5.5	44	14.5	3
6.0	44	15.0	2
6.5	21	15.5	1
7.0	49	16.0	0
7.5	36	16.5	0
8.0	46	17.0	1
8.5	25	17.5	1
9.0	38	18.0	3

The total yield of this acre was 5,207.5 pounds of green hops, and this divided by 853, the number of bearing hills, gives 6.104+ pounds as the average production per hill. Of the entire number of hills, 473 were below the average and 380 hills were above the average production. Also, the average production is only one-third of that reached in the case of a few hills.

According to the quantity of hops produced the hills may be roughly divided into three classes, or groups: (1) Those yielding less than 6 pounds, (2) those yielding from 6 to 12 pounds, and (3) those yielding more than 12 pounds. The first group consists of 429 hills, or 50.1 per cent of the entire number, and these produced only 1,380.5 pounds, or 26.5 per cent of the entire yield. The second group has 384 hills, or 45 per cent of the entire number, and the production was 3,261 pounds, or 62.6 per cent of the entire yield. The third group consists of 40 hills, or 4.7 per cent of the entire number, and the hops produced weighed 566 pounds, being 10.8 per cent of

the entire yield. The accompanying figure (fig. 2) shows graphically the relationship between these three groups.

Figure 2 will serve, also, in forming some conception of type with respect to yield from the hills of an entire field. A study of the hills of group 1 shows that for various reasons they are less productive than those usually regarded as average or representative hills. Similarly, the hills of group 3 are few in number and may be considered as exceptional and their occurrence expected far less often than that

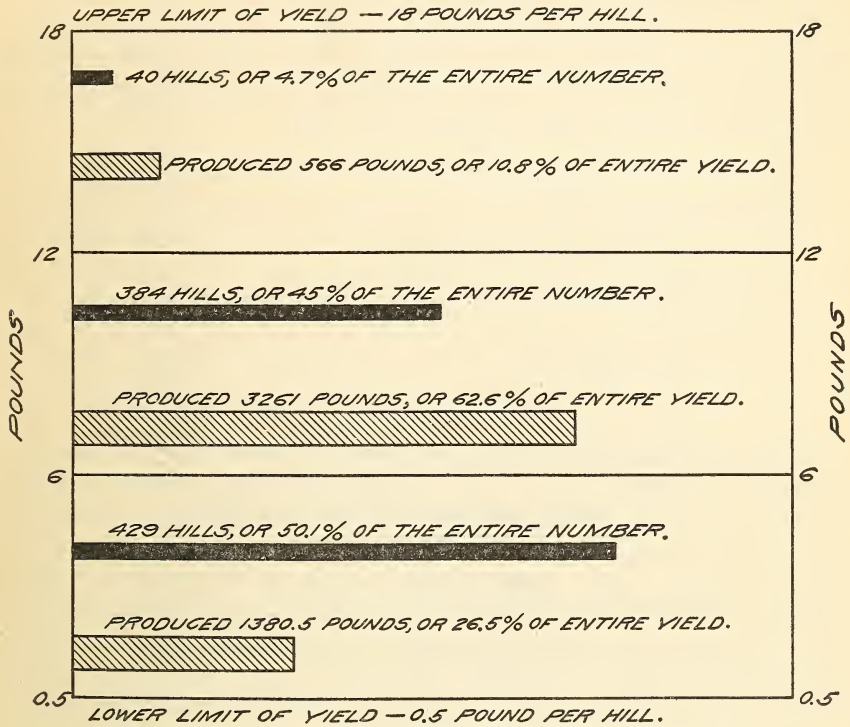

FIG. 2.—Diagram showing the ratio of the number of hills to the production of hops in three groups of low, medium, and high yielding hills.

of the hills of the other groups. It seems, therefore, that among the hills of group 2, where the bulk of the yield was obtained, the typical hills with respect to yield may be expected to occur. Assuming, then, that the prevailing type of normal hills with respect to yield lies between those producing 6 and those producing 12 pounds, there is every reason for giving special attention to the hills low in yield for the purpose of bringing them to a higher state of productiveness.

The fact should not be lost sight of that the average yield for this acre, 6.1+ pounds per hill, lies just above the lower limit of yield in

the second group. If through better methods of handling and closer attention to the details of culture the number of hills in the first group can be materially diminished, the average yield for the entire acre will be correspondingly advanced toward the upper limit of yield in the second group, and the total yield thereby substantially increased. In the following pages some suggestions will be given as to how this may be accomplished.

RELATION OF NUMBER OF VINES PER HILL TO YIELD.

The records obtained from the acre under observation show, further, that the number of vines trained from the individual hills varied from one to eight. The distribution of the hills according to the number of vines is shown in the following:

Hills having one vine	54
Hills having two vines	113
Hills having three vines	135
Hills having four vines	186
Hills having five vines	188
Hills having six vines	168
Hills having seven vines	8
Hills having eight vines	1
Total	853

Several explanations of the variation in vines to the hill may be advanced. Among them are the recent replanting of certain hills, in which case they would not have the vigor of older hills; the weakening of the roots of some hills by disease or the attacks of insects; the exhaustion of the vigor of others through long-continued production; the breaking off of a portion of the vines in cultivation; the destruction of some vines by the wind; or the cutting off of too many vines at the time of training. What seems most probable is that through the carelessness and negligence of the workmen the proper number of vines was not trained. It is probable, also, that individual differences in vigor and productiveness should be taken into account.

The relation between the number of vines per hill and the yield per hill is shown in Table III.

TABLE III.—*Comparison of the production of hops to the hill and the number of vines to the hill.*

Yield to the hill.	Number of vines to the hill—								Total number of vines.
	1.	2.	3.	4.	5.	6.	7.	8.	
Pounds.									
0.5	10	8							18
1.0	23	17	7	1	1	1			50
1.5	11	15	4	2	2				34
2.0	4	19	10	5	1				39
2.5	2	11	15	4	1				33
3.0	1	10	12	5	4				32
3.5	2	8	15	14	3	1			43
4.0	1	9	9	14	4	4			41
4.5		4	9	13	7	1	1		35
5.0		3	18	19	12	8			60
5.5		3	11	15	10	5			44
6.0		3	6	11	15	9			44
6.5			2	8	4	7			21
7.0		2	4	17	14	12			49
7.5				8	18	10			36
8.0			4	11	18	13			46
8.5			2	4	8	11			25
9.0		1	2	10	10	12	2	1	38
9.5			1	7	7	8	1		24
10.0			1	6	11	13			31
10.5			1		6	8	1		16
11.0				2	7	14	1		24
11.5			1	1	1	7			10
12.0				3	10	7			20
12.5				2	1	1	1		5
13.0				1	2	4			7
13.5					5	1			6
14.0			1	2	3	5			11
14.5					1	2			3
15.0						1	1		2
15.5					1				1
16.0									0
16.5									0
17.0				1					1
17.5						1			1
18.0					1	2			3
	54	113	135	186	188	168	8	1	853

In the first column of the table the yield per hill is given to the nearest half pound. The figures at the top of the following columns indicate the number of vines produced by each hill occurring therein, and the hills in each column are distributed according to their production to the nearest half pound. For example, from column 1 it will be seen that ten 1-vine hills produced 0.5 pound each, twenty-three 1-vine hills produced 1 pound each, etc.; from column 2 eight 2-vine hills produced 0.5 pound each, seventeen 2-vine hills produced 1 pound each; from column 3 seven 3-vine hills produced 1 pound each, four 3-vine hills produced 1.5 pounds each, and so on for the entire table. At the foot of the table the totals show the entire number of hills producing the number of vines indicated by the figure at the top of the respective columns.

A study of Table III will show that the larger numbers in each column occur in groups, but that the position of these groups with respect to the production per hill is very different. Thus (from column 1) 10, 23, and 11 hills produced 0.5, 1, and 1.5 pounds each,

respectively: (from column 3) 15, 12, and 15 hills produced 2.5, 3, and 3.5 pounds each, respectively; (from column 5) 14, 18, and 18 hills produced 7, 7.5, and 8 pounds each, respectively. From column 1 it appears that no 1-vine hill produced more than 4 pounds, and from column 6 that relatively few 6-vine hills produced less than 6.5 pounds each. The balance of evidence, therefore, is entirely in favor of a much larger total production when 6 vines to each hill are trained than with a smaller number.

COMPARISON OF ACTUAL WITH POSSIBLE YIELDS ON 1 ACRE.

The actual yield of hops on the acre studied was 5,207.5 pounds, and the mean yield per hill 6.104+ pounds. Had there been a full stand of 957 bearing hills, with this same average yield per hill, the production on the acre would have been 5,841.5 pounds. This is an increase of 12.1+ per cent over the actual yield.

In a similar manner, the possible yield per acre has been calculated for each number of vines trained per hill. For comparison the results have been brought together in Table IV, which follows:

TABLE IV.—*Possible yield on 1 acre of hops, according to the number of vines trained, with the corresponding increase or decrease of the possible over the actual yield.*

Number of vines to the hill.	Number of hills.	Actual yield.	Average yield to the hill.	Average yield to the vine.	Possible yield to the acre.	Increase or decrease of possible over actual yield.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*
1	54	71.5	1.324	1.324	1,257.0	[a] 75.8+
2	113	293.5	2.597	1.298	2,485.3	[a] 52.2+
3	135	585.5	4.337	1.445	4,150.5	[a] 20.2+
4	186	1,168.0	6.279	1.569	6,009.0	[b] 15.3+
5	188	1,488.5	7.917	1.583	7,576.5	[b] 45.4+
6	168	1,510.5	8.991	1.498	8,604.3	[b] 65.2+
7	[c] 8	81.0	10.125	1.446	.....	.....
8	[c] 1	.....	.....	.....	.....	.....

[a] Decrease. [b] Increase. [c] Number of hills too small for consideration.

The average yield to the hill was determined in each case by dividing the number of pounds produced by all of the hills having the same number of vines by the number of such hills. The possible yield was then obtained by multiplying the average yield per hill by 957, the number of possible bearing hills to the acre. It will be observed that the possible yield in the case of the hills having 1, 2, and 3 vines, respectively, is very much less than the actual yield, which was 5,207.5 pounds. Also, in the case of the hills having 4, 5, and 6 vines, respectively, the possible yield is far in excess of the actual, being 65.2+ per cent greater for the 6-vine hills.

It should be noted that the average yield per vine is fairly constant, irrespective of the number of vines to the hill. The average yield per vine for the entire acre also closely accords with these figures, being in this case 1.513 pounds per vine.

The averages given in Table IV may be considered as applying not only to the acre studied, but also in a general way to the entire crop in the section where this work was done. So long as the general conditions remain unchanged there is a high degree of probability that these averages will be found to represent fairly well what may be expected in succeeding years. Changed weather conditions, attacks of lice, mold, and spiders, or other unfavorable influences to which the hop crop is subject, will of course materially affect the chance of these averages being repeated. But they do show that a great increase in yield may be reasonably anticipated in fields in which there is a full stand and 6 vines are trained to each hill over the entire field when it presents the conditions existing on the acre which has furnished the data for these observations.

THE SO-CALLED "BASTARD" VINES.

In some sections hop vines are occasionally found which bear both staminate and pistillate flowers. Such plants are known locally as "bastards," "mongrels," or "bull-hops." When they occur they represent a total loss, so far as yield is concerned, since the few hops borne by these vines are inferior and never gathered. On the acre under consideration there were only five of these plants, but they have been observed in much greater proportion in other years and in other localities.

There is no evidence that these vines usually occur near a male vine, as stated by Myrick;[a] neither can an excess of pollen falling upon the pistillate flowers produce this abnormality, as is believed by some to be the case. Plants of this type frequently occur among seedling hops, and their presence may be expected in fields where chance seedlings springing up near the permanent hills have been trained in the usual manner. There are also good reasons for believing that this undesirable characteristic may be introduced through the root cuttings used in replanting or in setting out new fields. In 1908 a number of cuttings were taken from one of these "bastard" plants and removed to a locality about 40 miles distant. The vines from these cuttings came into flower in 1909 and in every case reproduced the malformation of the original plant from which they were taken. In view of this fact care should be taken to prevent the use of cuttings from "bastard" plants by promptly digging them out and destroying

[a] Myrick, H. The Hop, New York, 1899, p. 23.

the roots as soon as they are observed. In this way their perpetuation may be prevented and the loss in yield due to their occurrence avoided.

SUMMARY.

A critical study of yield on an acre of hops in California selected as representing the average condition of 600 surrounding acres shows that, owing to the occurrence of a large number of nonproductive and missing hills, the actual yield was only 87.9 per cent of what might be expected with a perfect stand.

The yield from individual hills was found to vary from 0.5 to 18 pounds. Owing to the large number of low-yielding hills the average yield per hill for the entire acre was reduced to 6.104+ pounds.

The number of vines trained to each hill varied from one to eight. As the number of vines per hill increased, the average yields of the hills having the same number of vines were found to increase in approximately the same ratio.

Assuming a full stand of 957 hills with 6 vines trained to each hill, the calculated possible yield is 65.2+ per cent greater than the actual yield on this acre.

"Bastard" or "mongrel" hills should be dug out and destroyed, as they are of no value and diminish the total yield.

Approved:

JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *March 7, 1910.*

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